

Jet Propulsion Laboratory
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A surface energy and mass balance model for the Ice Sheet System Model assimilation framework: integration and validation

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ISSM (Ice Sheet System Model) and the GEMB (Glacier Energy and Mass Balance) module

The GEMB module:

- was designed by Alex Gardner during his thesis work (Gardner and Sharp 2010)
- is a 1-D column model now integrated into ISSM, so it can be launched using the ISSM parallelized framework
- simulates the evolution of the snow pack including temporally evolving firn density profiles (FAC)
- forced by 3-hourly precipitation, solar irradiance, downwelling longwave radiation, near-surface wind speed, air temperature, and humidity

GEMB Module Simulated Processes

In addition, GEMB includes a detailed representation of surface and subsurface processes

- Surface albedo (four methods implemented)
(Gardner and Sharp 2010, Brun et al. 2009, Greuell & Konzelmann 1994, Bougamont & Bamber 2005)
- Sensible and latent heat fluxes
- Longwave emittance
- Melt-water generation
- Percolation and refreeze
- Pore water retention
- Snow compaction (three models implemented)
(Herron and Langway 1980, Arthern et al. 2006/2010, Li and Zwally 2004)
- Snow grain growth
- Thermal diffusion
- Subsurface absorption of shortwave radiation

Main Science Goal:

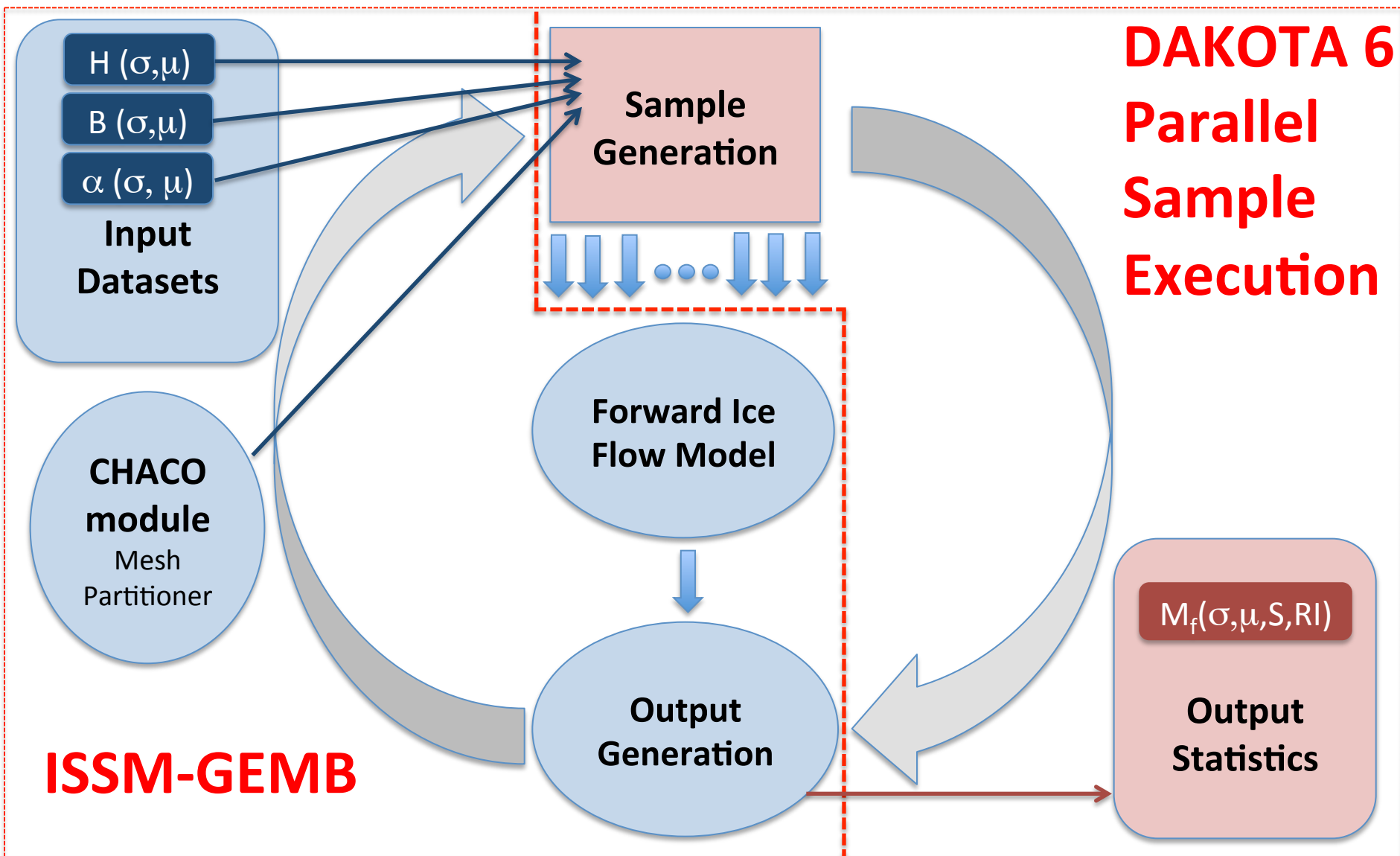
To better constrain uncertainty of local changes in ice mass when converting from altimetry-derived surface elevation changes (e.g. in ISSM assimilation of altimetry signals)

Current Strategy:

To conduct sensitivity and uncertainty quantification studies using GEMB/ISSM framework

- propagate errors from various climatological estimates of surface input into the top layers of the GEMB simulation, to better quantify uncertainties in the temporal evolution of key output (e.g. FAC).

Design Analysis Kit for Optimization and Terascale Applications (DAKOTA) software, embedded in ISSM



Sensitivity testing and uncertainty quantification

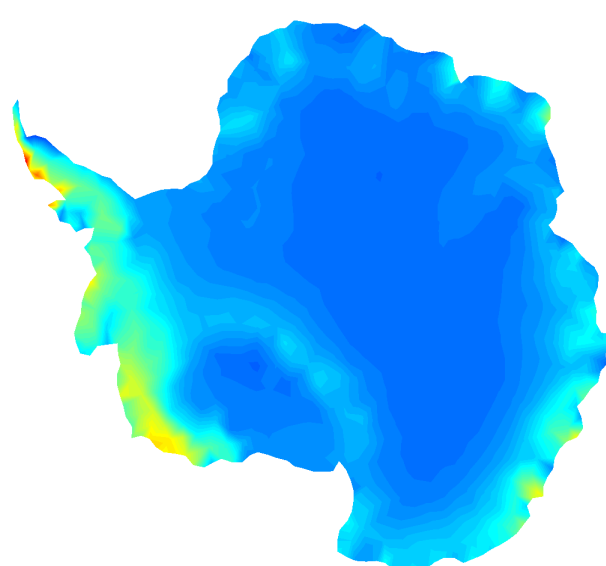
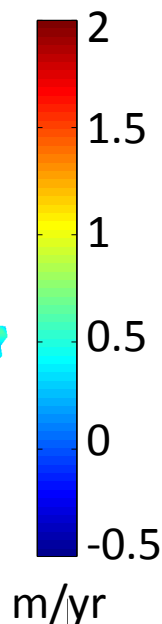
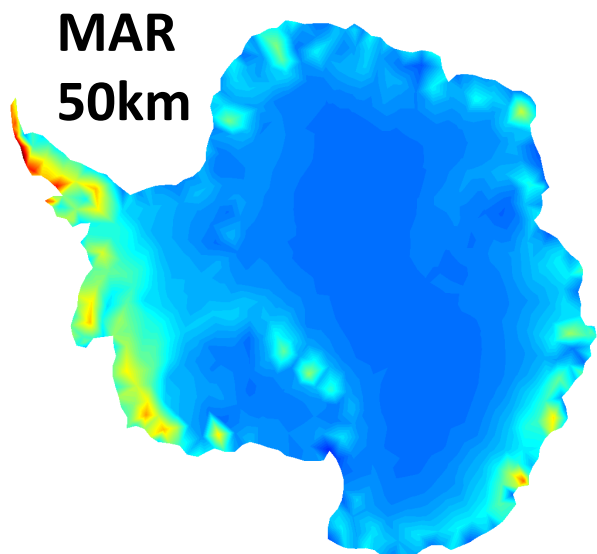
- Sensitivity Runs/Monte-Carlo style sampling
 - Run forced with different regional climate model input (RACMO, MAR)
 - Test result sensitivity to temporal and vertical resolutions
 - Run with different densification and albedo schemes
 - Near future: Update model to ingest observations in albedo (i.e. MODIS), so that we can run sampling techniques on albedo input
 - Perturb standardized climatology with anomalies generated from reanalysis (i.e. MERRA-2, CSR, NCEP-R2, ERA-Interim)
 - intra- and inter-annual variations in temperature, net radiative balance and precipitation

Example:

Simulation of Antarctica SMB and sensitivity
to albedo and densification schemes
with MAR

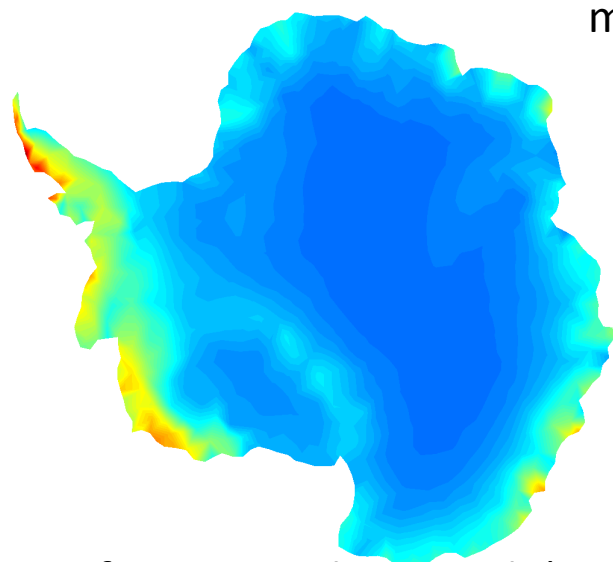
GEMB estimates of surface mass balance (1979-2015) with various schemes

MAR
50km



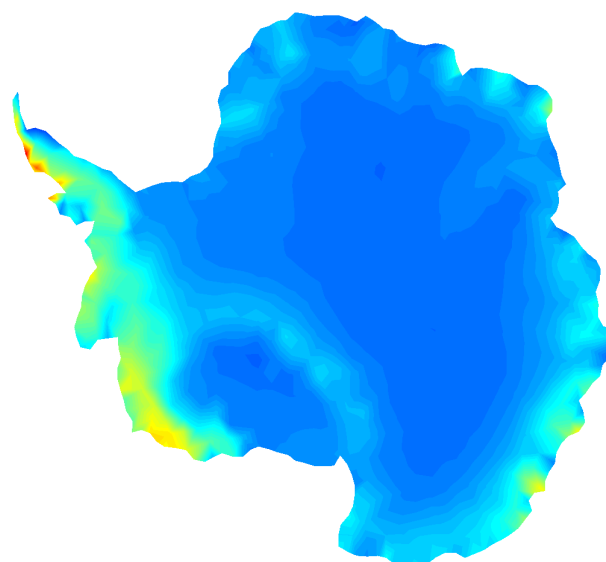
Densification: Arthern
et al. (2006)

Albedo: effective grain
radius [Gardner & Sharp,
2010]



Densification: Arthern et al. (2006)

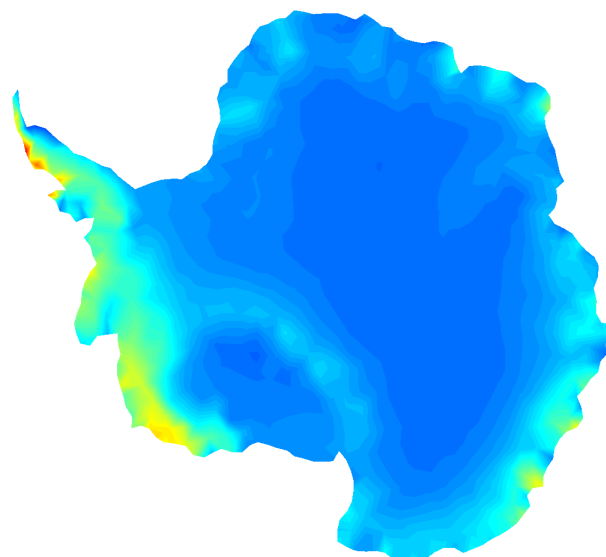
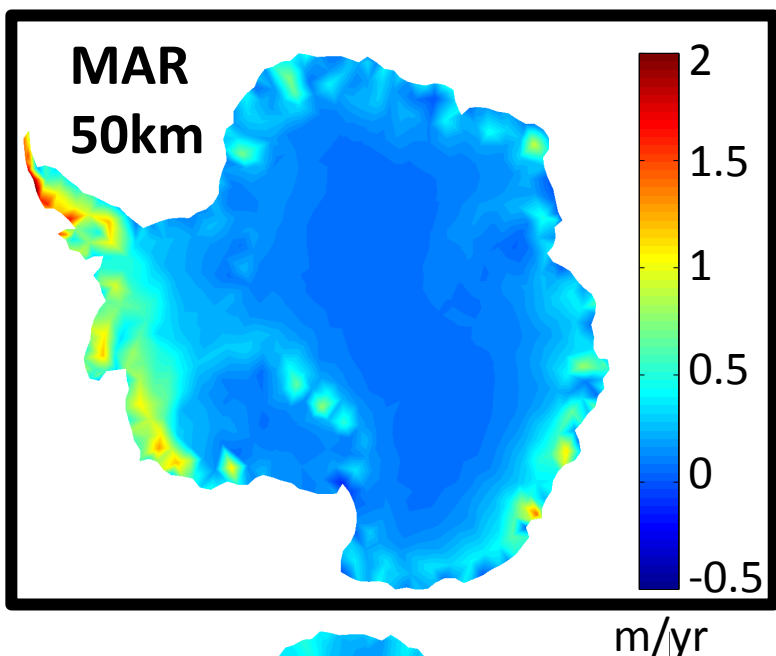
Albedo: density and cloud amount [Greuell & Konzelmann, 1994]



Densification: Herron &
Langway (1980)

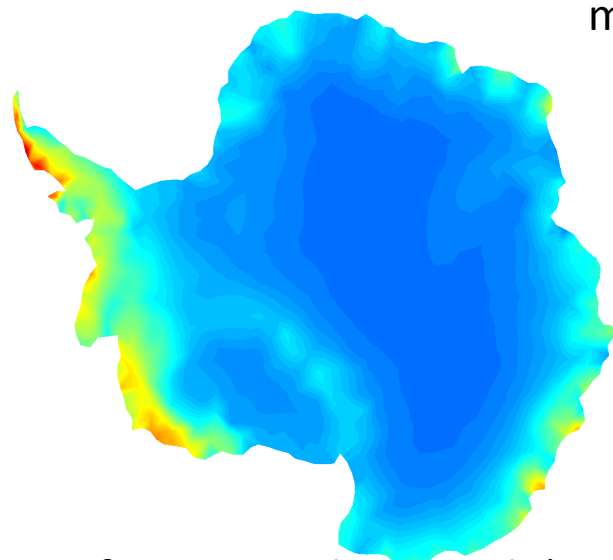
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GEMB estimates of surface mass balance (1979-2015) with various schemes



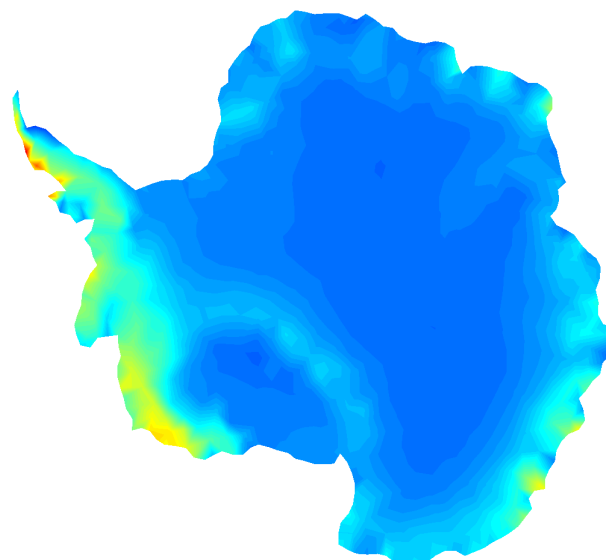
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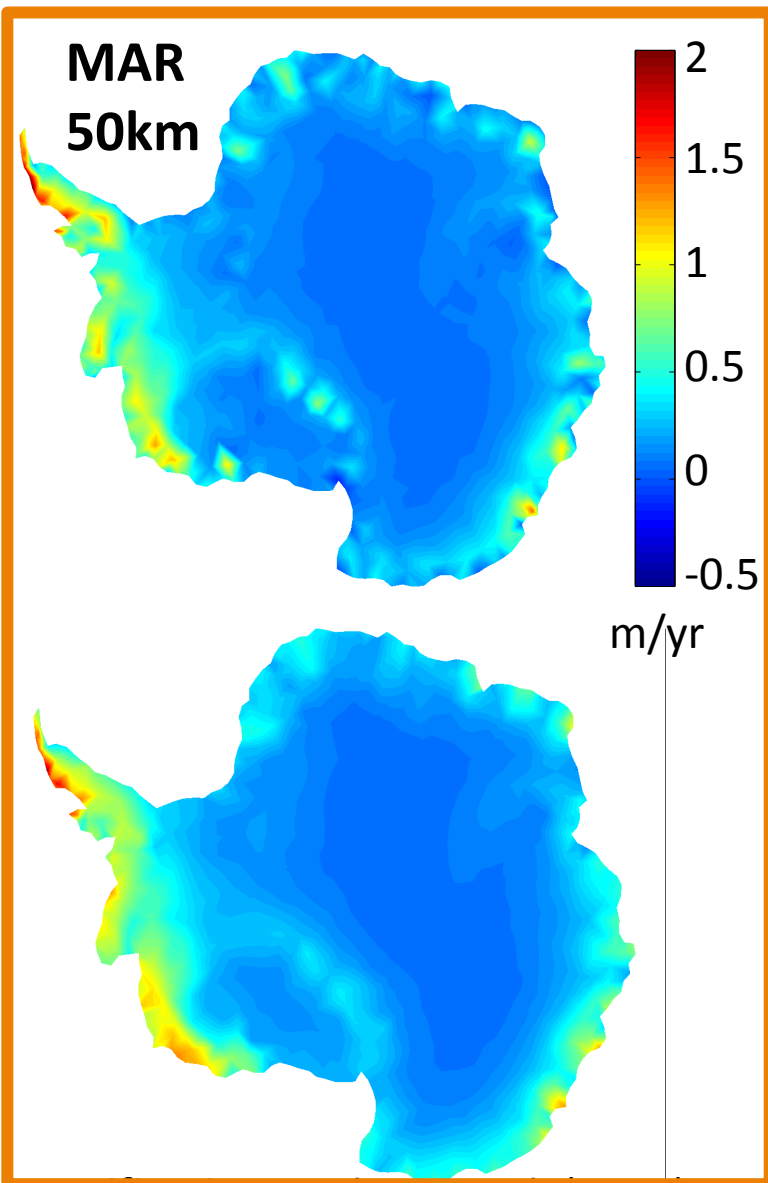
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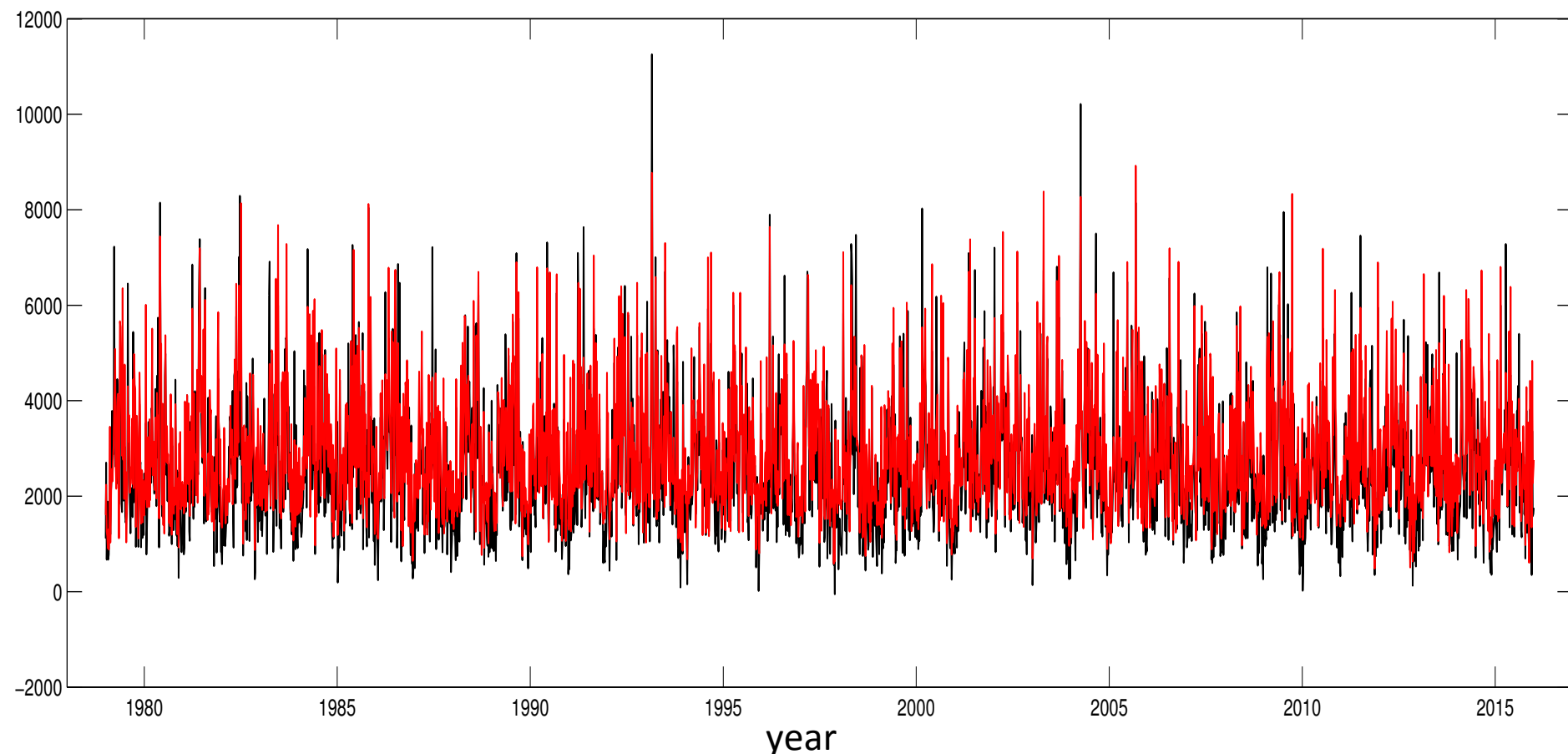
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Antarctica total SMB time series 1979-2015 vs. MAR

Gt/yr



— MAR SMB 50km
— GEMB SMB

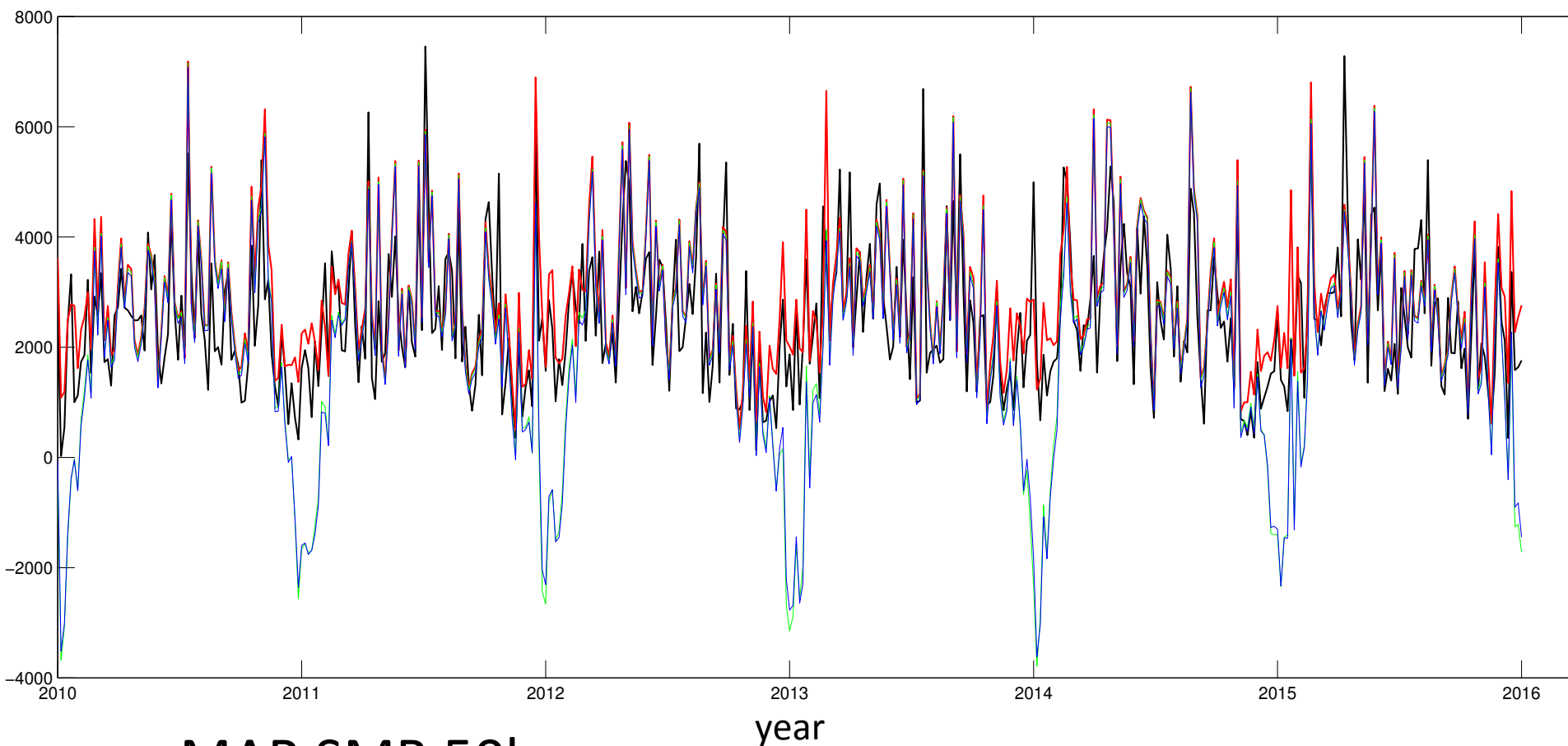
GEMB options

Densification: Arthern et al. (2006)

Albedo: density and cloud amount [Greuell & Konzelmann, 1994]

Antarctica total SMB time series 2010-2015 vs. MAR

Gt/yr



— MAR SMB 50km

— GEMB SMB (Arthern / Greuell & Konzelmann)

— GEMB SMB (Arthern / Gardner & Sharp)

— GEMB SMB (Herron & Langway / Gardner & Sharp)

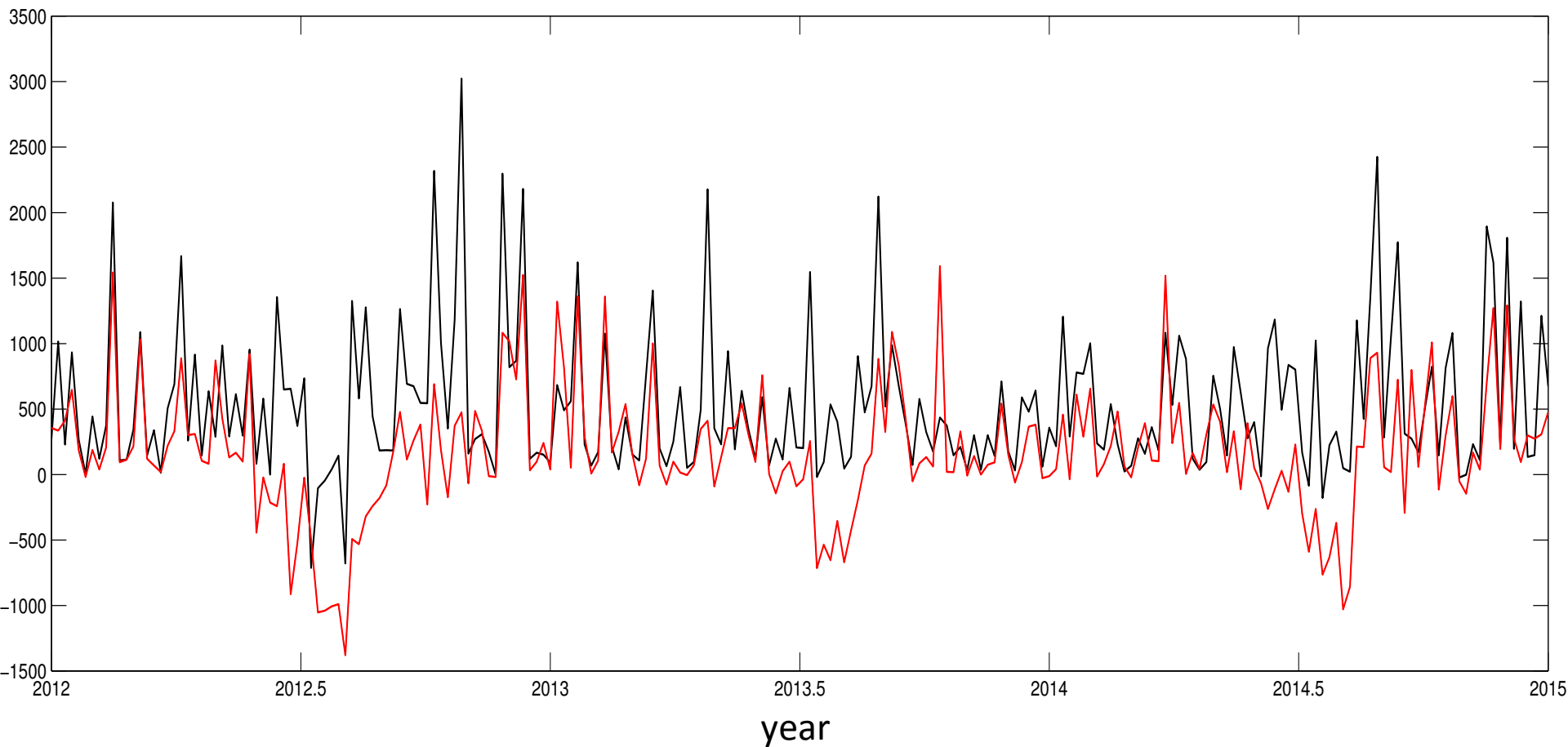
(Densification scheme / Albedo scheme)

Example:

Simulation of Greenland SMB and
firn properties
with RACMO

Greenland total SMB time series 2012-2014 vs. RACMO

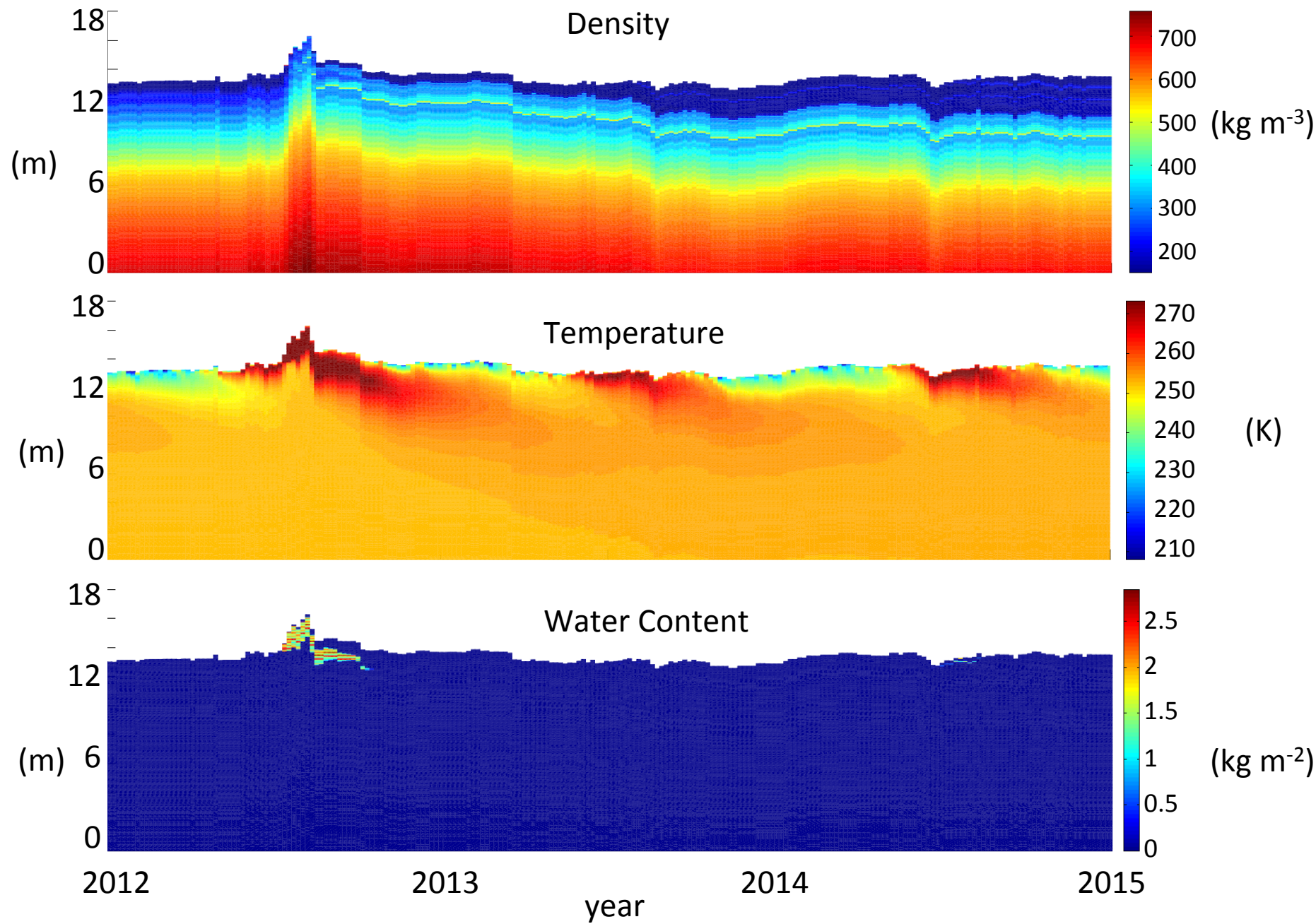
Gt/yr



— RACMO 2.3 (ZGRN11)

— GEMB SMB (Arthern / Greuell & Konzelmann)
(Densification scheme / Albedo scheme)

Greenland, Camp Century, GEMB estimates of firn properties (2012-2014)



Future Outlook

- Quantification of uncertainties and model bias will allow us to:
 - better constrain local changes in ice mass when converting from altimetry-derived surface elevation changes
 - characterize which surface forcing is most responsible for variations in surface elevation signals
- ✓ This is a significant assessment for the assimilation of altimetry signals into historical reconstructions using ISSM.
- ✓ In the future, analysis will aid in the reduction of the parameter space of surface forcing that must be weighted during ISSM reconstruction of surface change.
- ✓ This work will inform ISSM/altimetry assimilation with reasonable bounds for surface forcing that have the largest influence over surface elevation change.

Thank you!